Coloration and Growth of Red Lettuce Grown under UV-Radiation Transmitting and Non-Transmitting Covers

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Abstract

Production of red lettuce for salad mixes in Hawaii is primarily out-of-doors in the drier, leeward sides of the islands. Because the newer acrylic-polycarbonate hard covers transmit only small amounts of UV-radiation (which is essential for anthocyanin production), we experimented with a new ethylene-tetrafluoroethylene copolymer film (F-Clean), which transmits more than 90% of visible light and UV-radiation, for possible use in red lettuce production in high rainfall areas. Four cultivars of red lettuce, 'Natividad' - Red Lollo Rossa, 'Dark' - Lollo Rossa, 'Aruba' - Red Oak Leaf, and 'New Red Fire' - Red Grand Rapids, were grown in static hydroponic solution under each of the two levels of light and three UV-radiation environments. Lettuce plants with the most coloration and lowest head weight were produced out-of-doors with 100% UV-radiation. All of the lettuce produced under the non-UV-radiation transmitting, acrylic-polycarbonate cover had the least coloration and largest head weight. All were mostly green. Lettuce grown under the UV-radiation transmitting, F-Clean film with an additional layer of 50% aluminized shade screen were intermediate in color and head weight. The coloration of all the red lettuce studied appeared similar to 'Dark' - Lollo Rossa, where the anthocyanin, cyanidin 3-(6-malonyl) glucoside is present. UV-radiation appears to be the most important factor in coloration of red lettuce. Even with the additional layer of 50% shade, daytime temperatures were 4 to 6°C higher in the F-Clean house than in the acrylic-polycarbonate house. Yet, the cooler acrylic-polycarbonate house, which had little UV-radiation, produced green "red" lettuce with little coloration.

INTRODUCTION

Production of red lettuce under protected cultivation is often difficult, because many hard covers and films do not transmit the UV-radiation that is required for anthocyanin production. A new film "F-Clean" (ethylene-tetrafluoroethylene copolymer) manufactured by Asahi Glass of Japan is reported to transmit a large percentage of the UV-radiation. We grew four cultivars of red lettuce under this F-Clean film (with 50% shade cloth to reduce heat), under polycarbonate-acrylic hard cover ("Lexan") and out-of-doors to determine the effect of the two covers and UV-radiation on coloration and growth.

MATERIALS AND METHODS

Four cultivars of red lettuce, 'Natividad' - Red Lollo Rossa, 'Dark' - Lollo Rossa, 'Aruba' - Red Oak Leaf, and 'New Red Fire' - Red Grand Rapids, were grown in static hydroponic solution with 3 plants for each 2 gallon container. Three containers with nine plants of each cultivar were grown under each of two light and three UV-radiation environments: a) 100% light and 100% UV-radiation – out-of-doors, b) 50% light and 50% UV-radiation – under ethylene-tetrafluoroethylene copolymer (ETFE) F-Clean film with an additional layer of 50% aluminized shade cloth, c) 100% light and about 0% UV-

radiation – under polycarbonate-acrylic (PC-A) Lexan hard cover (see Fig. 1). After four weeks the heads were harvested and mean values calculated for head weight and color: lightness, chroma, hue (Konica-Minolta Chroma Meter CR-400) and photographed.

RESULTS

Growth

This preliminary study appears to show that the amount of UV-radiation is more important to growth of red lettuce than the amount of overall light.

1. Effect of Amount of Light. Heads of all four red lettuce cultivars grown with 100% light out-of-doors were smaller than heads grown with 50% light under ETFE film with 50% shade cloth. However, heads grown with 100% light under PC-A cover were larger than heads grown with 50% light under ETFE film with 50% shade cloth (Table 1).

2. Effect of Amount of UV-Radiation. Heads of all four red lettuce cultivars were larger when grown with very little or no UV-radiation under PC-A cover. Heads were smallest with 100% UV-radiation out-of-doors, and intermediate in size when grown with 50% UV-radiation under ETFE film with 50% shade cloth (Table 1).

Coloration

This preliminary study appears to show that the amount of UV-radiation is more important to coloration of red lettuce than the amount of overall light.

1. Effect of Amount of Light. Heads of all four red lettuce cultivars grown with 100% light out-of-doors were darker red in coloration than heads grown with 50% light under ETFE film with 50% shade cloth. Whereas, heads grown with 100% light under PC-A cover were mostly green and less red in coloration than heads grown with 50% light under ETFE film with 50% shade cloth (Table 2 and Fig. 2).

2. Effect of Amount of UV-Radiation. Heads of all four red lettuce cultivars were mostly green with the least amount of red coloration when grown with very little or no UV-radiation under PC-A cover. Heads were the darkest red with 100% UV-radiation out-of-doors, and intermediate in red coloration when grown with 50% UV-radiation under ETFE film with 50% shade cloth (Table 2 and Fig. 2). Thus, there appeared to be a direct correlation between UV-radiation and red coloration of leaves.

DISCUSSION

Previous studies have shown that UV-radiation is essential for anthocyanin pigmentation in leaves of several plants: *Arabidopsis thaliana* (Lois, 1994), *Cotinus coggygria* (Oren-Shamir and Levi-Nissim, 1997) and lettuce (Voipio and Autio, 1995). The UV-radiation has been shown to activate the flavonoid biosynthesis genes (Logemann et al., 2000). Krizek and co-workers (1998) have also shown that red lettuce grown with UV-A and UV-B radiation had increased levels of anthocyanins, but that only UV-B radiation affected flavonoid production. Our findings of increased levels of coloration, presumably from anthocyanins, induced by UV-radiation are in agreement with these reports. Our additional finding that reduction of the UV-radiation by 50% reduced the coloration of the lettuce leaves is of interest and we plan to examine anthocyanin and flavonoid levels in the leaves in response to varied levels of UV-radiation.

Anthocyanins in the red lettuce leaves were reported to increase with higher light intensity, cooler root zone temperatures and UV-A radiation (Voipio and Autio, 1995). In our study, 50% aluminized shade cloth was used in an attempt to reduce temperatures in the smaller frame greenhouse used for the F-Clean film. Temperatures were still in excess of 35°C on some days, in contrast to between 25°C and 30°C outside and in the polycarbonate-acrylic greenhouse (data not shown). However, good coloration still developed in the F-Clean greenhouse even with the 50% reduction in light intensity and warmer temperatures. Under the conditions of our study, it appeared that UV-radiation had a greater impact on coloration than cooler temperatures or light intensity.

Anthocyanins and flavonoids are reported to protect leaf cells from photo-oxidative damage from excess light and UV-radiation (Chalker-Scott, 1999; Feild et al., 2001). However, Krizek and co-workers (1998) report inhibitory effects of solar UV-A and UV-B radiation on lettuce growth. Our preliminary results also show reduced head weight with increasing levels of UV-radiation in all four cultivars of red lettuce. This reduced growth with UV-radiation may be due to the energy requirements for anthocyanin biosynthesis from chalcone to flavanone to dihydroflavonoids to leucoanthocyanins to anthocyanidins to anthocyanins (Jaakola, 2004). Nitsch and Nitsch (1959) have also reported that flavonoids and anthocyanins are either strong synergists or inhibitors of indoleacetic acid (IAA). In the case of red lettuce they may be inhibitors of auxin leading to reduced leaf growth.

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Tables

Table 1. Mean head weights of 4 cultivars of lettuce grown under 2 levels of light and 3 levels of ultraviolet light (in grams).

	Outside 100% light 100% UV	F-Clean + 50% shadecloth 50% light 50% uv	Lexan 100% light 0% UV
'Aruba' Oak Leaf	142.6±12.0	163.7±13.3	177.0±9.5
'Dark' Lollo Rossa	87.6±10.1	159.6±11.7	171.2±9.8
'Natividad' Red Lollo Rossa	124.2±4.6	152.3±7.0	176.1±10.1
'New Red Fire' Grand Rapids	170.3±13.4	228.1±10.9	228.8±12.0

Mean ± s.d.

Table 2. Mean color values: lightness, chroma, and hue for 4 cultivars of lettuce grown under 2 levels of light and 3 levels of ultraviolet light.

	Outside 100% light 100% UV	F-Clean + 50% shadecloth 50% light 50% uv	Lexan 100% light 0% UV
'Aruba' Oak Leaf	47.5, 31.9, 118.1	31.5, 8.01, 57.6	27.2, 5.2, 83.3
'Dark' Lollo Rossa	56.0, 41.7, 120.1	40.7, 16.8, 80.7	27.6, 10.9, 34.7
'Natividad' Red Lollo Rossa	58.7, 41.9, 119.0	34.3, 12.7, 71.8	27.0, 9.8, 21.2
'New Red Fire' Grand Rapids	54.5, 40.3, 117.4	33.4, 12.9, 82.0	27.8, 8.7, 30.6

Mean values from 6 leaf measurements for each cultivar.

Figures

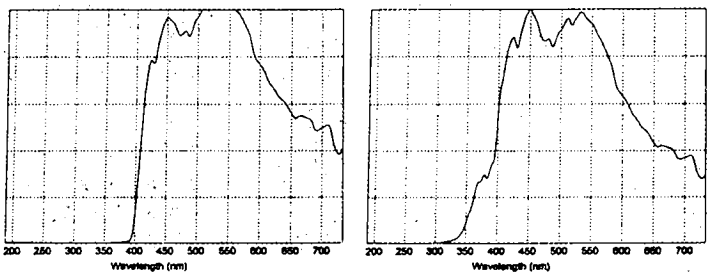

Fig. 1. Quality and relative intensity of light and UV-radiation passing through polycarbonate and acrylic Lexan hardcover (left) and ethylene-tetrafluoroethylene copolymer (ETFE) F-Clean film (right). UV-B is from 280 to 315 nm and UV-A is from 315-400 nm. UniSpec Spectral Analysis System from PP Systems.

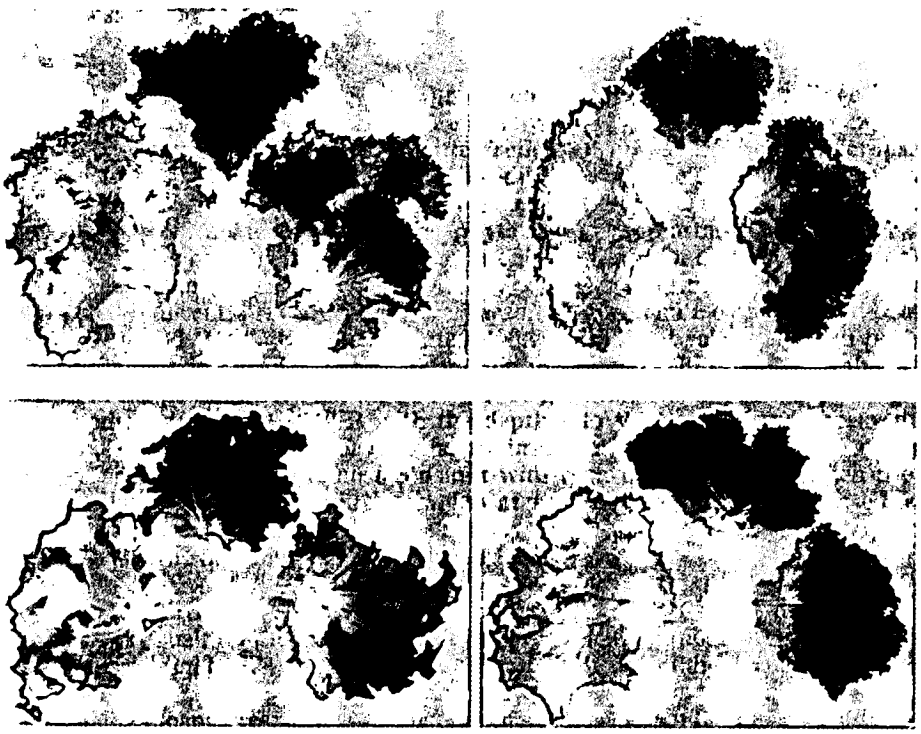

Fig. 2. Leaves of red lettuce cultivars: 'Natividad' Red Lollo Rossa – top left, 'Dark' Lolla Rossa – top right, 'Aruba' Oak Leaf – bottom left, 'New Red Fire' Grand Rapids – bottom right. In each photograph, 100% light and 100% UV-radiation – outdoors is at 12 o'clock, 50% light and 50% UV-radiation – ETFE F-Clean film with an additional layer of 50% aluminized shade cloth is at 4 o'clock, and 100% light and 0% UV-radiation – polycarbonate and acrylic Lexan hard cover is at 8 o'clock.